THOMSON COURSE TECHNOLOGY

Network+ Guide to Networks, Fourth Edition

Chapter 3
Transmission Basics and Networking Media

Objectives

- Explain basic data transmission concepts, including full duplexing, attenuation, and noise
- Describe the physical characteristics of coaxial cable, STP, UTP, and fiber-optic media
- Compare the benefits and limitations of different networking media
- Identify the best practices for cabling buildings and work areas
- Specify the characteristics of popular wireless transmission methods, including 802.11, infrared, and Bluetooth

Transmission Basics

- In data networking, transmit means to issue signals to the network medium
- Transmission refers to either the process of transmitting or the progress of signals after they have been transmitted

Analog and Digital Signals

- Information transmitted via analog or digital signals
  - Signal strength proportional to voltage
- In analog signals, voltage varies continuously and appears as a wavy line when graphed over time
  - Wave's amplitude is a measure of its strength
  - Frequency: number of times wave's amplitude cycles from starting point, through highest amplitude and lowest amplitude, back to starting point over a fixed period of time
    - Measured in Hz

Analog and Digital Signals (continued)

- Wavelength: distance between corresponding points on a wave's cycle
- Phase: progress of a wave over time in relationship to a fixed point
- Analog transmission susceptible to transmission flaws such as noise
- Digital signals composed of pulses of precise, positive voltages and zero voltages
  - Positive voltage represents 1
  - Zero voltage represents 0

Analog and Digital Signals (continued)

- Binary system: uses 1s and 0s to represent information
  - Easy to convert between binary and decimal
- Bit: a single binary signal
- Byte: 8 bits
  - Typically represents one piece of information
- Overhead: describes non-data information that must accompany data for a signal to be properly routed and interpreted

Data Modulation

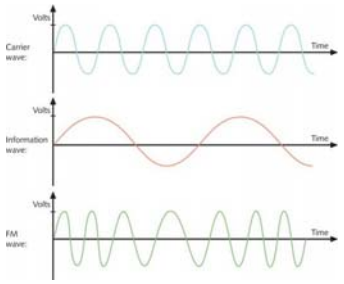

Figure 3-5: A carrier wave modified through frequency modulation

Transmission Direction: Simplex, Half-Duplex, and Duplex

- Simplex transmission: signals may travel in only one direction
- Half-duplex transmission: signals may travel in both directions over a medium
  - Only one direction at a time
- Full-duplex or duplex: signals free to travel in both directions over a medium simultaneously
  - Used on data networks
  - Channel: distinct communication path between nodes
    - May be separated logically or physically

Transmission Direction: Multiplexing

- Multiplexing: transmission form allowing multiple signals to travel simultaneously over one medium
  - Channel logically separated into subchannels
- Multiplexer (mux): combines multiple signals
  - Sending end of channel
- Demultiplexer (demux): separates combined signals and regenerates them in original form
  - Receiving end of channel

Relationships Between Nodes

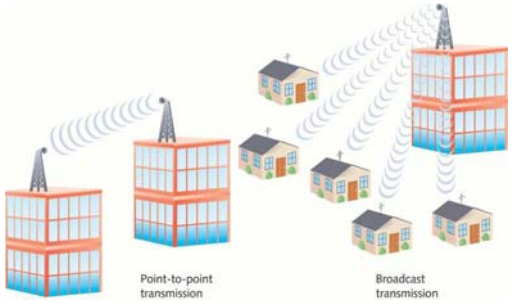

Figure 3-10: Point-to-point versus broadcast transmission

Throughput and Bandwidth

- Throughput: measure of amount of data transmitted during given time period
- Bandwidth: difference between highest and lowest frequencies that a medium can transmit

Baseband and Broadband

- Baseband: digital signals sent through direct current (DC) pulses applied to a wire
  - Requires exclusive use of wire's capacity
  - Baseband systems can transmit one signal at a time
  - Ethernet
- Broadband: signals modulated as radiofrequency (RF) analog waves that use different frequency ranges
  - Does not encode information as digital pulses

Transmission Flaws: Noise

- electromagnetic interference (EMI): waves emanating from electrical devices or cables
- radiofrequency interference (RFI): electromagnetic interference caused by radiowaves
- Crosstalk: signal traveling on a wire or cable infringes on signal traveling over adjacent wire or cable
- Certain amount of signal noise is unavoidable
- All forms of noise measured in decibels (dB)

Attenuation

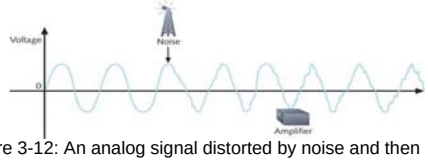

Figure 3-12: An analog signal distorted by noise and then amplified

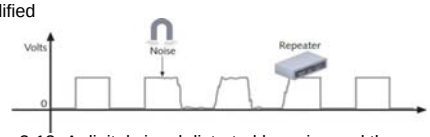

Figure 3-13: A digital signal distorted by noise and then repeated

Latency

- Delay between transmission and receipt of a signal
  - Many possible causes:
    - Cable length
    - Intervening connectivity device (e.g., modems and routers)
- Round trip time (RTT): Time for packets to go from sender to receiver and back
- Cabling rated for maximum number of connected network segments
- Transmission methods assigned maximum segment lengths

Common Media Characteristics: Throughput

- Probably most significant factor in choosing transmission method
- Limited by signaling and multiplexing techniques used in given transmission method
- Transmission methods using fiber-optic cables achieve faster throughput than those using copper or wireless connections
- Noise and devices connected to transmission medium can limit throughput

Cost

- Many variables can influence final cost of implementing specific type of media:
  - Cost of installation
  - Cost of new infrastructure versus reusing existing infrastructure
  - Cost of maintenance and support
  - Cost of a lower transmission rate affecting productivity
  - Cost of obsolescence

Size and Scalability

- Three specifications determine size and scalability of networking media:
  - Maximum nodes per segment
    - Depends on attenuation and latency
  - Maximum segment length
    - Depends on attenuation, latency, and segment type
    - Populated segment contains end nodes
  - Maximum network length
    - Sum of network's segment lengths

Connectors and Media Converters

- Connectors: pieces of hardware connecting wire to network device
  - Every networking medium requires specific kind of connector
- Media converter: hardware enabling networks or segments running on different media to interconnect and exchange signals
  - Type of transceiver
    - Device that transmits and receives signals

Noise Immunity

- Some types of media are more susceptible to noise than others
  - Fiber-optic cable least susceptible
- Install cabling away from powerful electromagnetic forces
  - May need to use metal conduit to contain and protect cabling
- Possible to use antinoise algorithms

Coaxial Cable

- High resistance to noise; expensive
- Impedance: resistance that contributes to controlling signal (expressed in ohms)
- Thickwire Ethernet (Thicknet): original Ethernet medium
  - 10BASE-5 Ethernet
- Thin Ethernet (Thinnet): more flexible and easier to handle and install than Thicknet
  - 10BASE-2 Ethernet

Twisted-Pair Cable

- Color-coded pairs of insulated copper wires twisted together
- Twist ratio: twists per meter or foot
  - Higher twist ratio reduces crosstalk and increases attenuation
- TIA/EIA 568 standard divides twisted-pair wiring into several categories
  - Level 1 or CAT 3, 4, 5, 5e, 6, 6e, 7
- Most common form of cabling found on LANs today

STP (Shielded Twisted-Pair)

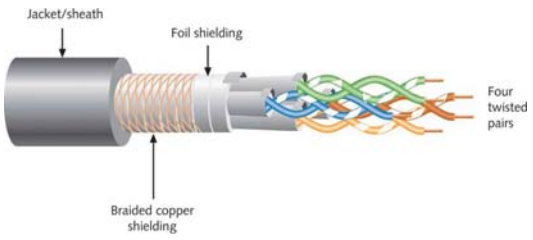

Figure 3-18: STP cable

UTP (Unshielded Twisted-Pair)

- Less expensive, less resistant to noise than STP
- Categories:
  - CAT 3 (Category 3): up to 10 Mbps of data
  - CAT 4 (Category 4): 16 Mbps throughput
  - CAT 5 (Category 5): up to 1000 Mbps throughput
  - CAT 5e (Enhanced Category 5): higher twist ratio
  - CAT 6 (Category 6): six times the throughput of CAT 5
  - CAT 6e (Enhanced Category 6): reduced attenuation and crosstalk
  - CAT 7 (Category 7): signal rates up to 1 GHz

Comparing STP and UTP

- Throughput: STP and UTP can both transmit data at 10, 100, and 1000 Mbps
  - Depending on grade of cabling and transmission method used
- Cost: STP usually more expensive than UTP
- Connector: Both use RJ-45 and RJ-11
- Noise Immunity: STP more noise-resistant
- Size and scalability: Max segment length for both is 100 m on 10BASE-T and 100BASE-T networks
  - Maximum of 1024 nodes

10BASE-T

- Fault tolerance: capacity for component or system to continue functioning despite damage or partial malfunction
- 5-4-3 rule of networking: between two communicating nodes, network cannot contain more than five network segments connected by four repeating devices, and no more than three of the segments may be populated

100BASE-T (Fast Ethernet)

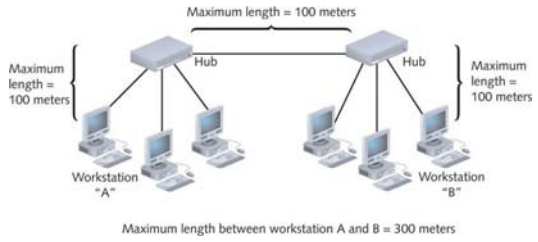

Figure 3-23: A 100BASE-T network

Fiber-Optic Cable

- Contains glass or plastic fibers at core surrounded by layer of glass or plastic cladding
  - Reflects light back to core

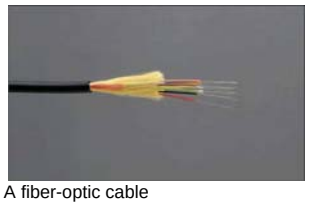

Figure 3-24: A fiber-optic cable

SMF (Single-mode Fiber)

- Narrow core through which laser-generated light travels over one path, reflecting very little
  - Accommodates high bandwidths and long distances
  - Expensive

MMF (Multimode Fiber)

- Benefits over copper cabling:
  - Nearly unlimited throughput
  - Very high resistance to noise
  - Excellent security
  - Ability to carry signals for much longer distances before requiring repeaters than copper cable
  - Industry standard for high-speed networking

MMF (continued)

- Throughput: transmission rates exceed 10 Gigabits per second
- Cost: most expensive transmission medium
- Connector: 10 different types of connectors
  - Typically use ST or SC connectors
- Noise immunity: unaffected by EMI
- Size and scalability: segment lengths vary from 150 to 40,000 meters
  - Optical loss: degradation of light signal after it travels a certain distance away from its source

Summary of Physical Layer Standards

Standard	Maximum Transmission Speed (Mbps)	Maximum Distance per Segment (m)	Physical Media	Topology*
10BASE-T	10	100	CAT 3 or higher UTP	Star
10BASE-FL	10	2000	MMF	Star
100BASE-TX	100	100	CAT 5 or higher UTP	Star
1000BASE-T	1000	100	CAT 5 or higher UTP (CAT 5e is preferred)	Star
1000BASE-CX	1000	25	Twinaxial cable	Star
100BASE-FX	100	2000	MMF	Star
1000BASE-LX	1000	Up to 550, depending on wavelength and fiber core diameter	MMF	Star
		5000	SMF	Star

Table 3-2: Physical layer networking standards

Summary of Physical Layer Standards (continued)

Standard	Maximum Transmission Speed (Mbps)	Maximum Distance per Segment (m)	Physical Media	Topology*
1000BASE-SX	1000	Up to 500, depending on modal bandwidth and fiber core diameter	MMF	Star
10GBASE-SR	10,000	Up to 300, depending on modal bandwidth and fiber core diameter	MMF	Star
10GBASE-LR	10,000	10,000	SMF	Star
10GBASE-ER	10,000	40,000	SMF	Star

Table 3-2 (continued): Physical layer networking standards

Cable Design and Management

- Cable plant: hardware making up enterprise-wide cabling system
- Structured cabling: TIA/EIA's 568 Commercial Building Wiring Standard
  - Entrance facilities point where building's internal cabling plant begins
    - Demarcation point: division between service carrier's network and internal network
  - Backbone wiring: interconnection between telecommunications closets, equipment rooms, and entrance facilities

Cable Design and Management (continued)

- Structured cabling (continued):
  - Equipment room: location of significant networking hardware, such as servers and mainframe hosts
  - Telecommunications closet: contains connectivity for groups of workstations in area, plus cross connections to equipment rooms
  - Horizontal wiring: wiring connecting workstations to closest telecommunications closet
  - Work area: encompasses all patch cables and horizontal wiring necessary to connect workstations, printers, and other network devices from NICs to telecommunications closet

Installing Cable

- Many network problems can be traced to poor cable installation techniques
- Two methods of inserting UTP twisted pairs into RJ-45 plugs: TIA/EIA 568A and TIA/EIA 568B
- Straight-through cable allows signals to pass "straight through" between terminations
- Crossover cable: termination locations of transmit and receive wires on one end of cable reversed

Wireless Transmission

- Networks that transmit signals through the atmosphere via infrared or RF waves are known as wireless networks or wireless LANs (WLANs)

The Wireless Spectrum

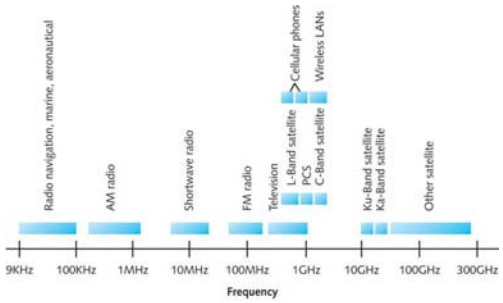

Figure 3-37: The wireless spectrum

Characteristics of Wireless Transmission

Figure 3-38: Wireless transmission and reception

Antennas

- Radiation pattern describes relative strength over three-dimensional area of all electromagnetic energy the antenna sends or receives
- Directional antenna issues wireless signals along a single direction
- Omnidirectional antenna issues and receives wireless signals with equal strength and clarity in all directions
- Range: geographical area an antenna or wireless system can reach

Signal Propagation

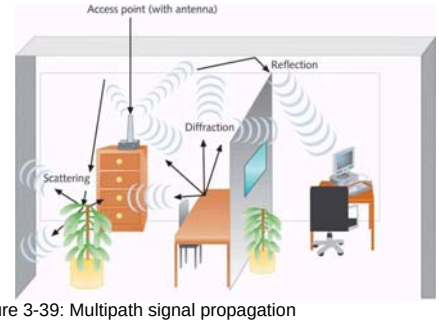

Figure 3-39: Multipath signal propagation

Signal Degradation

- Fading: change in signal strength resulting from electromagnetic energy being scattered, reflected, or diffracted after being issued by transmitter
- Wireless signals experience attenuation
  - May be amplified and repeated
- Interference is significant problem for wireless communications
  - Atmosphere saturated with electromagnetic waves

Narrowband, Broadband, and Spread Spectrum Signals

- Narrowband: transmitter concentrates signal energy at single frequency or in very small range of frequencies
- Broadband: uses relatively wide band of wireless spectrum
  - Offers higher throughputs
- Spread spectrum: use of multiple frequencies to transmit a signal
  - Frequency hopping spread spectrum (FHSS)
  - Direct sequence spread spectrum (DSSS)

Fixed versus Mobile

- Fixed wireless system: locations of transmitter and receiver do not move
  - Point-to-point link
  - Efficient use of signal energy
- Mobile wireless system: receiver can be located anywhere within transmitter's range
  - More flexible

Infrared Transmission

- Transmitted by frequencies in the 300-GHz to 300,000-GHz range
- Most often used for communications between devices in same room
  - Relies on the devices being close to each other
  - May require line-of-sight path
  - Throughput rivals fiber-optics

Wireless LAN (WLAN) Architecture

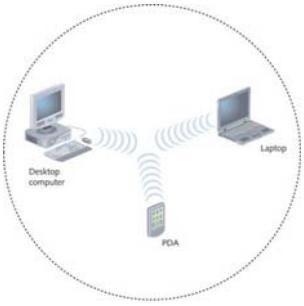

Figure 3-40: An ad-hoc WLAN

Wireless LAN Architecture (continued)

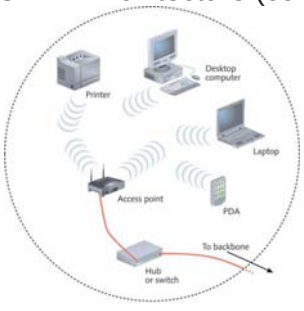

Figure 3-41: An infrastructure WLAN

Wireless LAN Architecture (continued)

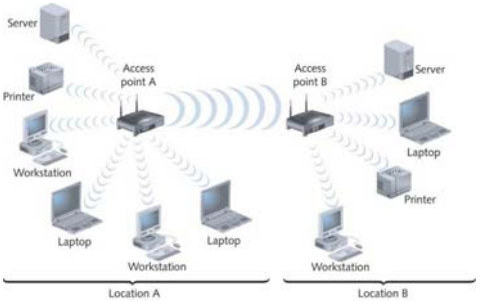

Figure 3-42: Wireless LAN interconnection

Summary

- Information can be transmitted via two methods: analog or digital
- In multiplexing, the single medium is logically separated into multiple channels, or subchannels
- Throughput is the amount of data that the medium can transmit during a given period of time
- Baseband is a form of transmission in which digital signals are sent through direct current pulses applied to the wire
- Noise is interference that distorts an analog or digital signal

Summary (continued)

- Analog and digital signals may suffer attenuation
- Cable length contributes to latency, as does the presence of any intervening connectivity device
- Coaxial cable consists of a central copper core surrounded by a plastic insulator, a braided metal shielding, and an outer plastic cover (sheath)
- Twisted-pair cable consists of color-coded pairs of insulated copper wires
- There are two types of twisted-pair cables: STP and UTP

Summary (continued)

- There are a number of Physical layer specifications for Ethernet networks
- Fiber-optic cable provides the benefits of very high throughput, very high resistance to noise, and excellent security
- Fiber cable variations fall into two categories: single-mode and multimode
- Structured cabling is based on a hierarchical design that divides cabling into six subsystems

Summary (continued)

- The best practice for installing cable is to follow the TIA/EIA 568 specifications and the manufacturer's recommendations
- Wireless transmission requires an antenna connected to a transceiver
- Infrared transmission can be used for short-distance transmissions